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DESIGNING AND PROGRAMMING GAME-BASED LEARNING WITH HUMANOID ROBOTS: A CASE STUDY OF THE MULTIMODAL "MAKE OR DO" ENGLISH GRAMMAR GAME WITH THE PEPPER ROBOT

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Abstract

Game-based learning (GBL) is a popular approach to designing engaging educational experiences enhancing motivation and enjoyment while at the same time supporting the attainment of learning outcomes. Robot-assisted language learning (RALL) based on game-based learning with humanoid robots is becoming an interesting area of human-robot interaction (HRI) which has the potential to enrich educational curricula. Studies have shown that interacting with a humanoid robot as part of language learning may be beneficial for learner motivation and improvement across a range of language skills, especially speaking accuracy, fluency, and pronunciation. Both RALL and GBL can reduce learning anxiety and enhance positive attitudes towards learning grammar, which tends to be perceived as boring and complicated by language learners. This paper presents an instructional design and programming of a game-based learning scenario for learning English grammar in higher education, in which the humanoid robot Pepper is used as a game partner. The scenario is called "Make or Do Game with Pepper" and is intended as an educational, interactive quiz in two versions, i.e. a single player version and a team-based version. This paper presents the first version of the game for one-on-one play between the human and the robot. This version of the game was tested with a small group of five students in Digital Business Studies. The game consists of two main parts: the interaction with the Pepper robot and the tablet application which is fixed to the chest of the robot. The results from the pilot study show that students enjoyed playing the grammar game with the Pepper robot, and perceived the robot as a friendly, kind, pleasant, funny and relaxed game partner which appeared good-humoured, jocular, funny, relaxed and interested. The paper also describes what the participants liked and what they did not like about the game, and which recommendations were made for future iterations The paper ends with a conclusion and recommendations for further research.

Keywords: Robot-assisted language learning (RALL), human-robot interaction (HRI), game-based learning (GBL), Pepper robot, English grammar, grammar game, English as a Foreign Language (EFL).

1 INTRODUCTION

Game based learning (GBL) is a popular approach to designing engaging educational experiences enhancing motivation and enjoyment while at the same time supporting the attainment of learning outcomes. A review of 114 published papers on game-based language learning, reveals that game-based approaches to language learning focus primarily on vocabulary acquisition, specific input skills (mostly reading and listening) and output skills (mostly writing and speaking) [1]. The most frequently occurring elements in game-based language learning designs also include different feedback types (such as corrective feedback and scores for correct responses), themes (including settings or characters consistent within a game), narratives (including different techniques of storytelling), points (such as points for completing tasks, challenges, battles), as well as levels and progression (mostly related to increasing difficulty and improvement of skills) [1]. Other elements include such mechanisms as time pressure, exploration and signposting [1]. At the same time, there are some gaps in research, for example, research on game-based learning of grammar language skills have been scarce [1]. Moreover, most of the published papers have focused on children and only a few studies were conducted with adult learners and university students [1]. From this perspective, this paper adds to current research by providing results from a pilot study with a robot-assisted game-based application for the learning of grammar skills for university students.

Robot-assisted language learning (RALL) is becoming an interesting area in human-robot interaction (HRI) and has a potential to enrich educational curricula. Studies in the area of RALL have explored the uses of a wide range of educational robots programmed to serve as teaching assistants. A number of studies have emphasised specific benefits for language learning, such as creating a relaxed learning experience with less social pressure, enhancing the self-confidence and motivation of language learners, and contributing to the diminution of the strategy of many language learners to avoid speaking a foreign language they are learning [2]. Educational robots, including humanoid robots, provide a tangible embodiment of technology, which has been shown to enhance interaction with and provide engaging learning experiences for language learners [2]. A number of recent studies have shown how language learners may benefit from using educational robots. For example, the study by [3] indicated that using a robot and a tablet to support learning of English of EFL adult learners is beneficial not only for motivation but also for the improvement of a range of language skills, especially speaking accuracy, fluency, and pronunciation.

As proposed by [2] humanoid robots have at least ten characteristics that may be exploited to support language learning. These are (1) *repeatability* (repeated practice without fatigue or negative emotion enhances comprehension, skill development and familiarity), (2) *flexibility* (robots can be programmed in an individual way and educators do not have to rely on specific instructional materials developed by a manufacturer), (3) *digitalisation* (especially in respect to the flow and documentation of data related to learning), (4) *humanoid appearance* (which makes robots to a more engaging technology which enhances curiosity and motivation to learn), (5) *body movement and motion* (which helps combine speaking with gestures), (6) *interaction* (such as engaging in dialogues and reacting to human responses based on language recognition), (7) *anthropomorphism* (contrary to other educational media, humanoid robots are perceived as human-like language speakers), (8) *sensing capability, intelligence and automatic speech recognition* (which enable robots to sense the environment and communicate with humans and computers), (9) *language understanding and dialogue management* (robots can be programmed to understand the utterances of language learners despite errors), (10) *emotional expression* (robots can represent different emotions such as joy, disapprobation, sadness, or embarrassment, and can make accompanying gestures such as waving or cheering) [2].

The use of games in language is not uncommon and a current meta-analysis on the effectiveness of using games strategies in English language learning and teaching indicated that games may support the development of a range of language skills including vocabulary, reading, writing, listening and speaking, but that it is uncommon to use games in teaching grammar skills [4]. Although game-based scenarios for Robot Assisted Language Learning (RALL) have been advocated by a number of authors [5], design and research in game-based RALL with humanoid robots is still in its infancy. So far, there have been only a few publications specifically related to game-based robot assisted language learning using humanoid robots. There are a few studies which explore the role of feedback during game-based interactions of children with educational robots in the context of language learning. For example, using game-based approaches in RALL was shown to enhance the motivation of language learners [5]. In the “I spy with my little eye” game, the humanoid robot was effectively employed as a tutor providing children with different types of feedback to facilitate second language learning [6]. Another study conducted with children showed that playing a storytelling game with a social robot was beneficial for language learning, especially for the emulation of the robot's he robot’s use of language, as well as in the area of new vocabulary acquisition [7]. In a review of 22 RALL journal articles, [8] Randall reports that the most common language teaching methodologies used in RALL are CLT (Communicative Language Teaching), TPRS (Teaching Proficiency through Reading and Storytelling), TPR (Total Physical Response), and ALM (Audiolingual Method), and that most RALL studies focus on schoolchildren aged between 7 and 12 years, as well as pre-schoolers (aged between 4 and 7). The authors suggest that the reason for this may be because these are critical and formative years for language learning [8]. While most of the studies in RALL in the past were conducted with children, studies on game-based RALL with adult populations are now becoming more common. For example, a study involving L2 language learners (i.e. second language learners) with the support of an anthropomorphic robot, aimed at determining a suitable pedagogical set-up for adult learners, concluded that the adult learners were most active when the robot encouraged learner to learner interaction [9]. In another study focused on adults, the robot head Furhat was used to test the HRI as well as the human to human interaction between test subjects in teaching scenarios where the robot assumed different interlocutory roles [10]. The authors concluded that RALL may be used successfully with adult learners, but that the proficiency level of learners has a determinative effect on the specific interlocutory role that the robot should play [10].

2 METHODOLOGY

The humanoid robot Pepper was applied as the robotic platform for the English language grammar game “Make or Do Game with Pepper” for adult university students. Iterative methodology was followed to develop the application for the Pepper robot. The development included a number of phases such as requirement engineering, design, implementation and testing. The following sections describe these phases in more detail.

2.1 Requirements engineering

In the first step of development, a sample application for the Pepper robot was demonstrated in a university language learning class to understand whether adult learners (students) were interested in game-based learning with a humanoid robot at all. In the next step, the requirements of the “Make or Do Game with Pepper” application were collected based on students’ interest during their interaction with the Pepper robot in the classroom. The first results showed that students were interested in playing the game with the Pepper robot and some of the key functional requirements included: (1) the application must have a practice and test option; (2) the robot must understand the voice command Yes/No; (3) the robot should produce sad/happy animation depending on student‘s answer; (4) the application must read questions, answers and write student scores to the Firebase database; (5) the application must display the score, the descending time limit, and a verbal warning before the time limit expires; (6) teachers must be able to change the questions and answers in the database. Besides these functional requirements, some further requirements were added based on the past experiences in designing game-based applications, such as shuffling questions, not repeating questions during the test, Pepper robot loudly asking students questions using speech, and filling in the correct answer with green colour when the given answer by the students is wrong.

2.2 Application design

The design of the application “Make or Do Game with Pepper” is based on the iterative design procedure and used use case diagrams and architecture diagrams to visualise the design process. The use case diagrams were used to summarise the information about users or actors in a system and their interactions with the system. Fig. 1 shows the current use case diagram of the “Make or Do Game with Pepper” application.

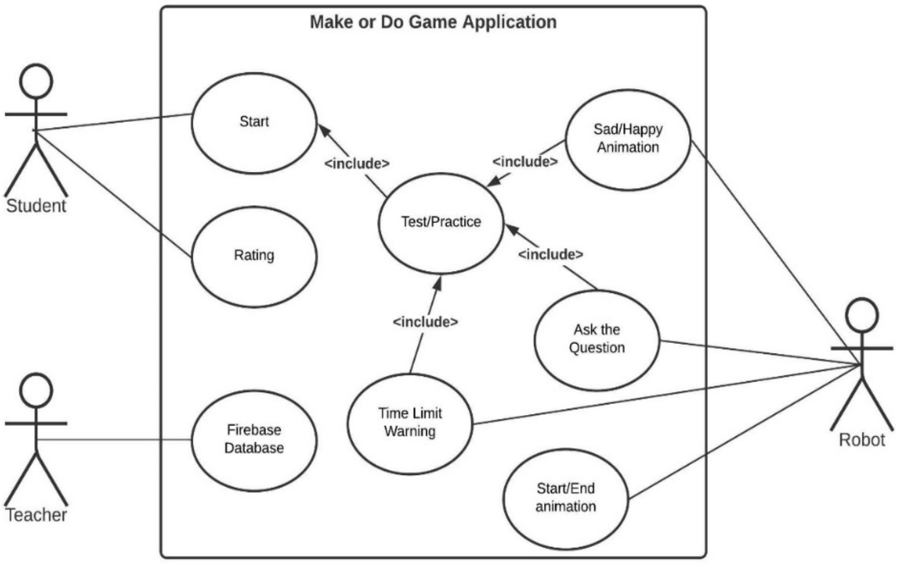


Figure 1. Use case diagram of the “Make or Do Game with Pepper” application.

Two primary actors (student, teacher) and one secondary actor (robot) are used to represent the use case diagram of the application. The student can start the game and select an option either Test or Practice. Once the student selects the Test or Practice option, the actions such as Sad/Happy, Time limit warning, Ask question, are started sequentially. At the end of the practice or test, the student can evaluate the application. The teacher can edit the questions, answers and the number of questions asked in the test or exam using the database settings. The Pepper robot produces sad and happy animations based on the answers from the student. It also produces a welcome animation at the beginning and a closing animation at the end of the session.

To design the programme logic, the Model-View-Controller (MVC) architecture pattern was used as a popular software development pattern. MVC pattern splits the application into 3 components: Model, View and Controller. Where the Model component of the “Make or Do Game with Pepper” application is responsible for the communication with the database, the View component is the user interface that offers interaction to the users and the Controller component establishes the relationship between the Model and View component. The Controller component contains the core application logic and activates the robot animation. Fig. 2 shows the applied MVC architecture pattern.

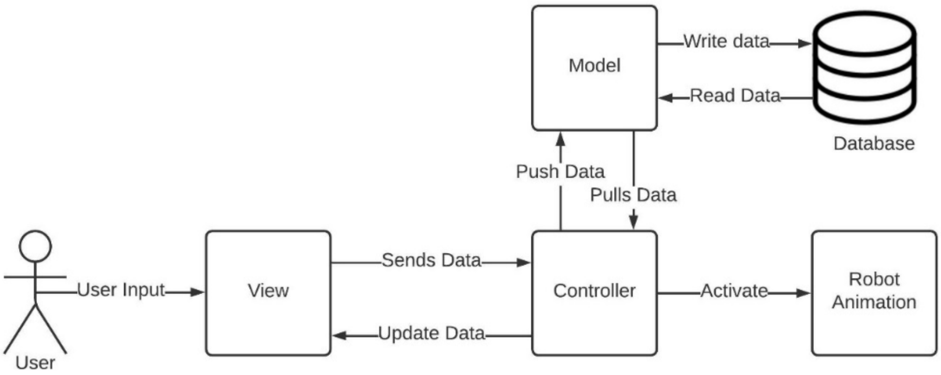


Figure 2. Architecture of the “Make or Do Game with Pepper” application.

2.3 Implementation

The Android Studio IDE (Integrated Development Environment) and the Kotlin programming language were used to develop the algorithm of the "Make or Do Game with Pepper" application. Integrating third-party libraries for text-to-speech, speech-to-text, and robot animations was the main challenge in implementing the “Make or Do Game with Pepper” application and meeting the requirements listed in the section above. Fig. 3 shows the flowchart of the algorithm used in the application.

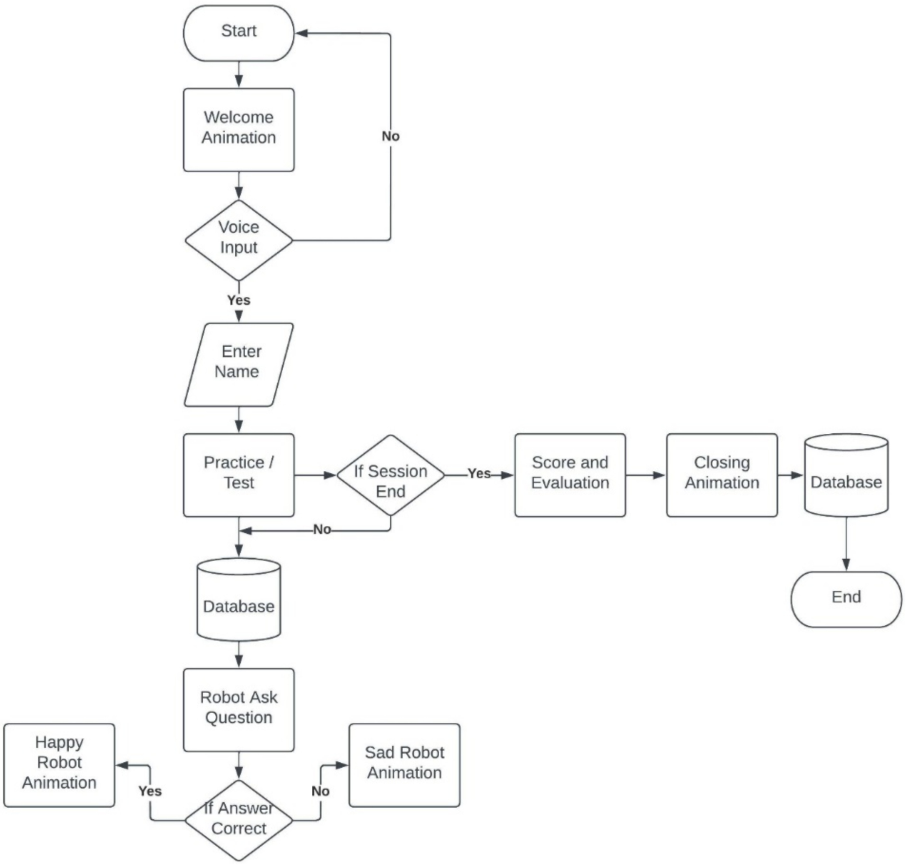
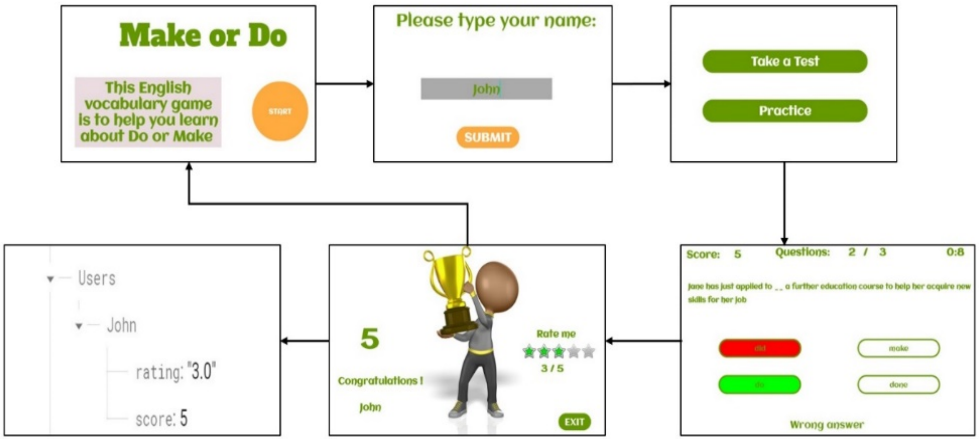


Figure 3. Flowchart of the “Make or Do Game with Pepper” application algorithm

Once the start button of the application is pressed, the Pepper robot starts the welcome animation and speech. After the user's voice input, the application asks for the user name and displays the options, for example, Test or Practice. Once the user selects the Test or Practice option, the application displays the question and answer from the database, and at the same time, the Pepper robot speaks the question aloud with a blank in the position of the answer. For the test option, there is a time limit for the user to answer, but for the exercise option, there is no time limit. The Pepper robot produces a sad or happy animation depending on the user's answer. At the end of the session, after 10 questions or so, the application displays the user's final score and asks for a rating. As soon as the user presses the button to exit the application, the robot starts the closing speech and animation, and stores the score, rating, and the user's name in the database.

2.4 Testing of the “Make or Do Game with Pepper” application

The humanoid robot Pepper is controlled by the Android tablet attached to its chest according to the instruction manual provided by the manufacturer SoftBank Robotics. SoftBank Robotics' Kotlin libraries were integrated to animate the Pepper robot in order to develop the "Make or Do Game with Pepper" application. Several tests were performed to verify the stability of this application and the application passed all the tests with a good result. Fig. 4 and Fig. 5 show the testing result and Pepper robot animations.



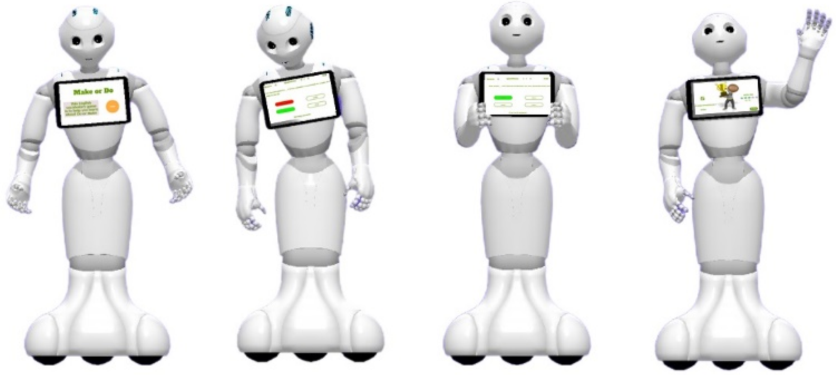
Make or Do

This English vocabulary game is to help you learn about Do or Make

Please type your name:

Jane has just applied to __ a further education course to help her acquire new skills for her job

Figure 4. The “Make or Do Game with Pepper” application views on the tablet.



Welcome Sad Happy Closing

Figure 5. Pepper robot animations of the Make or Do Game application.

In the first phase of Fig. 4, when the user presses the circled start button, the Pepper robot starts the welcome animation shown in Fig. 5 in parallel with a welcoming speech such as "I am very pleased to meet you. May I know your name? Please say yes or no." Once the word “Yes” is recognised by the Pepper robot, the second phase of Fig. 4 appears. The user must enter the name and press the "Submit" button in the second phase to take a test or for the practice. In the 4th phase of Fig. 4, the user presses the wrong answer in the test option of the 3rd phase, which turns red and the correct answer turns green. In this phase, the sad animation of the Pepper robot is activated in parallel with the encouraging speech for the next question. The same happens in case of a correct answer from the user with a happy animation. In phase 5 of the process of Fig. 4, the score is displayed along with the user's name and the Pepper robot asks for a rating. If the user presses the “Exit” button at this phase, the Pepper robot starts the closing animation shown in Fig. 5 in parallel with the closing speech and stores the data in the database shown in Phase 6 of Fig. 4. The process continues until the “Make or Do Game with Pepper" application is turned off.

2.5 Design of the study

The pilot study took place on university campus in June 2022, at the end of the summer semester 2022. The participation in the study was voluntary. The pilot study consisted of three parts and started with students answering initial questions in an online survey. Next, the students participated in the “Make or Do Game with Pepper” and then, in the last part, answered follow-up questions in the same online survey. The key research questions for the pilot study were: *What are the expectations of students towards a humanoid robot facilitating a language learning game? How did students perceive the humanoid robot Pepper as a game partner? How did students experience the language learning game with Pepper and which improvements to the game would students recommend?* The following sections present the results from the pilot study including the characteristics of the study sample and the results related to each of the research questions.

3 RESULTS

The results from the online survey during the pilot study with five students are described below in relation to each of the research questions. The IBM SPSS software, version 27 was used for the analysis.

3.1 Study sample

The participants in the study were students in the Bachelor study program in Digital Business, who participated in the course on Learning Design in the 6th semester of their studies. In total five students filled in the online-survey before and after playing the “Make or Do” game. The sample was comprised of 60% male and 40% female participants. 60% of the participants were aged 20 to 24 years old, 20% 30 to 34 years old and 20% 35 to 39 years old.

3.2 Expectations and perceptions of the Pepper robot

The first two research questions for the pilot study were: (1) *What are the expectations of students towards a humanoid robot facilitating a language learning game?,* and (2) *How do students perceive the humanoid robot Pepper as a game partner?* There were altogether four questions in the online survey related to these research questions. The first question about the expectations, i.e. *What do you expect from the game “Make or Do” with Pepper?,* was asked before the game and the second question related to expectations, i.e. *How well did the game meet your expectations?*, was asked after playing the game. The questions about the perception of the Pepper robot as game partner were asked after the game and included two questions: *How did you perceive Pepper as a game partner?*, and *How did you perceive the mood of Pepper as a game partner?*

The questions were answered by the participants in the following way:

1 *What do you expect from the game “Make or Do” with Pepper?* This question was an open question in which students could write their own answers. Students expected fun and games, human-like interaction with the Pepper robot and thought they would have to imitate something Pepper says.

2 *How well did the game meet your expectations?* This question was rated on a scale from 1 = “my expectations were not met at all” to 6 = “my expectations were fully met”. The mean value was M = 4.80 (SD = .837) indicating that most students felt that the game met their expectations.

3 *How did you perceive Pepper as game partner?* This question was answered by rating five pairs of semantic items from the Likeability Scale of the Godspeed questionnaires [11]. Using semantic pairs of adjectives is a semantic differential method, which is popular in research on human robot interaction. For example, the popular Godspeed questionnaires include five questionnaires using semantic differential scales used to assess perceptions of different attributes of robots such as anthropomorphism, animacy, liveability, perceived intelligence and safety [11]. Unlike the Likert scale, wich presents a series of statements on a symmetric agree-disagree scale, the semantic

differential scales ask participants to choose the most appropriate anchor items between two bipolar words [11]. Data obtained from semantic differential scales can be treated just as any other rating data [11]. The study presented in this paper used one of the five Godspeed questionnaires related to “Likeability”. The Likeability Scale consists of five semantic pairs of words. The items are rated on a scale from 1 = “unlikeable”, “unfriendly”, “unkind”, “unpleasant”, “awful” to 6 =. “likeable”, “friendly”, “kind”, “pleasant”, “nice”. Table 1 below summarises the results from the analysis of data related to the Likeability Scale.

Table 1. Perception of the Pepper robot as a game partner.

	unlikeable (1) ***likeable (6)***	***unfriendly (1)*** ***friendly (6)***	***unkind (1)*** ***kind (6)***	***unpleasant (1)*** ***pleasant (6)***	***awful (1)*** ***nice (6)***
Mean	5.00	5.40	5.60	5.20	5.60
Std. Deviation	1.000	.894	.894	1.304	.894

These results show that high values equal to 5 and above 5 points where reached on the scale from 1 to 6, which indicates that the participants perceived the Pepper robot as a likeable, friendly, kind, pleasant, and nice game partner. Additionally, the internal consistency of the scale was computed and resulted in a high value of α=.934 (Cronbach’s Alpha), indicating the excellent consistency of the Likeability Scale.

4 *How did you perceive the mood of Pepper as game partner?* This question was answered by rating five pairs of semantic items on a scale from 1 = “sad”, “serious”, “in a bad mood”, “stressed”, “bored” to 6 =. “merry”, “funny”, “in good mood”, “relaxed”, “interested”. These pairs of words were inspired by Godspeed questionnaires and self-constructed to assess the perception of the robot’s mood. Table 2 below summarises the results from the analysis related to the perceived mood of the robot.

Table 2. Perception of the mood of the Pepper robot as a game partner.

	sad (1) ***merry (6)***	***serious (1)*** ***funny (6)***	***in bad mood (1)*** ***in good mood (6)***	***stressed (1)*** ***relaxed (6)***	***bored (1)*** ***interested (6)***
Mean	5.40	5.20	5.40	5.00	5.20
Std. Deviation	.894	1.304	.894	1.000	1.304

These results show that high values equal to 5 and above 5 points where reached on the scale from 1 to 6, which indicates that the participants perceived the Pepper robot to be merry, funny, in a good mood, relaxed, and interested. Additionally, the internal consistency of the scale was computed and resulted in a very high value of α=.986 (Cronbach’s Alpha), indicating an excellent internal consistency of this newly developed scale.

3.3 Experience of the “Make of Do” game with Pepper

The next research questions for the pilot study were: How did students experience the language learning game with Pepper and which improvements to the game would students recommend? There were altogether three open questions in the online survey related to these research questions. Participants could formulate their own answers to each of the question, i.e. What did you like about the “Make of Do” Game with the Pepper robot?; What did you not like about the “Make of Do” Game with the Pepper robot?, and Which recommendation do you have for the improvement of the “Make of Do” Game with the Pepper robot in the next iterations?

The questions were answered by the participants in the following way:

1 *What did you like about the “Make of Do” Game with the Pepper robot?* Students emphasised the following elements which they liked about the game: the interaction with the robot, the use of the tablet and the implementation of the game on the tablet of the Pepper robot, the verbal answers from the Pepper robot, and the feedback in the game.

2 *What did you not like about the "Make of Do" Game with the Pepper robot?* Students criticised the following elements which they did not like about the game: missing display about system state, too few gestures of the robot before and after the game, the very loud volume of the voice of the robot in the English language, and the fact that the Pepper robot did not read the sample sentences aloud.

3 *Which recommendation do you have for the improvement of the "Make of Do" Game with the Pepper robot in the next iterations?* The following recommendations on improving the human-robot interaction were expressed by the participants: include a system display, explain rules of the game briefly and concisely before beginning the game, incorporate gestures of the robot more explicitly into the gameplay, adjust the volume, increase eye contact. The participants also formulated a few recommendations related to the content of the game and recommended using other tense forms for make and do phrases, and to end sample sentences with a selection of suitable signal words (such as always, yesterday, today).

4 CONCLUSIONS

This paper presented the design and programming of the application "Make or Do" Game with the humanoid robot Pepper and the results from a pilot study with a small group of five university students, who played the game with Pepper and evaluated the human-robot interaction. The results from the pilot study indicate that the expectations of the students towards a robot-led language learning game were met to a large extent and that the participants perceived the Pepper robot as a likeable, friendly, kind, pleasant, and nice game partner, who was merry, funny, in a good mood, relaxed, and interested. Furthermore, both the Likeability Scale from the Godspeed questionnaires and the newly developed semantic differential scale for the assessment of the mood of the robot showed excellent internal consistency. Finally, the participants in the pilot study enjoyed interacting with the Pepper robot and considered using the tablet as a helpful element in the game. However, there were also a few critical points, primarily related to the high volume of robot's voice and to an insufficient inclusion of gestures. In summary, it could be observed that the participating students experienced the "Make or Do" game with the Pepper robot as an enjoyable and exciting experience. However, following up on the research about the possible positive influence of the "novelty effect" on learners' willingness to engage with humanoid robots, which for most learners are new and previously unencountered classroom technologies [8], [9], [10], the authors of this paper recommend conducting further research based on longer term studies and using larger sample sizes to properly assess the pedagogical effectiveness of game-based RALL using humanoid robots.

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